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С.-ПЕТЕРБУРГЪ.

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Russian Coprolites.

Among the compounds of phosphoric acid most easily assimilated by plants, one of the foremost places must be assigned to calcium phosphate. In nature phosphate of lime is found in the form of the minerals apatite and phosphorite *). Their chemical composition is identical, namely $Ca^3 (PO_4)^2$, but they are distinguished from each other by the mode in which their molecules are combined among themselves, a phenomenon known to chemists as polymerism or allotropic modification. Apatite, representing a crystalline variety of phosphorite, is a very stable body, and by itself not adapted for use as a fertiliser, not being assimilable by plants.

Phosphorites present two varietes. In the first, phosphate of lime does not appear in the form of sharply defined crystals, but merely shews a crystalline structure. This group occupies a mid position between the apatites

*) The term used in Russian for several kinds of phosphatic minerals. It would perhaps be more accurate than the word *coprolite*, which is however in popular use.

and the next group of phosphorites containing amorphous phosphate of lime. It approaches apatite in stability. Introduced into the soil as a fertiliser, the powder obtained from grinding phosphorites of the kind in question is very slowly assimilated by plants, resembling in this respect the supply already contained in the soil. For this purpose, both apatites and these phosphorites must be preliminarily transformed by the action of acids into the assimilable form, that is, into superphosphate or reverted (precipitated) phosphate powder (the monocalcic compound). The second variety of phosphorites contains amorphous phosphate of lime. The powder obtained from them affords an excellent fertiliser. Its action is the more rapid, the finer it has been ground.

All three forms of mineral phosphate occur in European Russia. Apatite containing 92 to 95 per cent. of calcium phosphate is found in the Ural mountains and the Caucasus. A transitional form of phosphorite closely resembling it is met with in clayey schists belonging to the Siberian system occurring in the government of Podolia. It has the form of large bowlders. A considerable quantity of this kind of phosphorite goes abroad, where it is transformed into superphosphate. Samples contain from 60 to 80 per cent. of calcium phosphate.

The third kind called amorphous phosphorite is found in immense beds in various parts of Russia. They are situated over the whole of the northern border of the cretaceous basin between the rivers Dvina and Kama, in tertiary, Jurassic and diluvial formations. They occupy a vast area of about twenty million desiatins (54 million acres) spread over the following governments: Kursk (with 18 to 20 per cent. phosphoric acid), Oriol, Riazan, Penza, Tambov, Voronezh, Simbirsk, Nizhni Novgorod, Kostroma (25 to 30 per cent.), Yaroslav, Tver, Moscow (18 to 26 per cent.), Smolensk, Vitebsk, Pskov, Kiev and Podolia.

Phosphorites are met with in different parts of Russia in the form of plates, nodules, cylinders and bowlders. Deposits also occur in the form of a sandy conglomerate, knitted together with calcium phosphate as a cement.

The chemical composition of the different phosphorites is extremely various, the result mainly of the different proportions existing between the cement and the matrix. The quantity of phosphoric acid in the cement itself is usually about 30 per cent., while in the phosphorite it is from 3 to 30 per cent. Well preserved fossils occur in phosphorites, in the shape of the remains of saurians,

fishes' teeth, mollusks, sponges, pieces of wood and coprolites.

On the boundary between the cretaceous and Jurassic systems, lies the so-called Aucellar stratum, which received its name from the fossil shell belonging to the genus Aucella characteristic of this formation. The rocks of this layer are various. Thus, near Moscow it consists of marly sandstone, in the neighbourhood of Simbirsk of calcareous sandstone, while in the government of Riazan it is composed of dense green sandstone and greensands. The latter consist of grains of glanconite and quartz knitted together with a cement of phosphorites. The glanconite, which here and there occurs to the extent of 24 per cent., contains about 8 per cent. of potash, so that it serves at the same time as a potash fertiliser. The layers of the Aucellar stratum containde about 18 per cent. of phosphoric acid and 2 per cent. of potash.

As to the origin of phosphorites, it is generally held that they are all derived from animal remains. This view is supported, in the first place, by the almost constant presence of a small admixture of organic matter, and secondly, by that of osteolites or the fossilised bones, and coprolites or the fossil excreta, of animals belonging to former geological periods.

both of which betray an undoubted organic origin. As to other phosphorites not exhibiting these evidences, it is supposed that they were produced in the following manner. Water containing carbonic acid dissolved by degrees the bones, shells and other remains of the inhabitants of the Mesozoic and Cenozoic ages, and then, filtering through into the strata of sand below, there deposited phosphate and carbonate of lime after yielding up a portion of the carbonic acid gas. As this process went on, the various sandstones were cemented together by the phosphates thus deposited. In this way phosphorites were formed in the shape of nodules, stalactitic masses, «géodes» and tumours. They were no doubt produced in the same manner as the lime masses called by German geologists «lösspuppchen», as is shewn by their very similar internal structure. The physical and chemical laws, however, according to which the latter were formed have not yet been satisfactorily explained. Plates of pure phosphorite were due to the same process, a theory supported by the occurence on them of growths in the shape of stalactites covering sometimes the whole of their under surface.

The presence of phosphorites in Russia was pointed out long ago. The first to do this was

the teacher Selivanov in 1818, but at that time no attention whatever was paid to his discovery. At the end of the forties, Murchison and Count Kayserling determined the presence of beds of phosphorites near Kursk, the former however mistaking them for ferruginous sandstone. At the end of the forties Mr. Yazykov first drew attention to their importance for Russian agriculture. The first analysis of this mineral was made by Khodnev in 1850, who shewed that it contained as much as 31 per cent. of phosphoric acid.

In the year 1866, A. N. Engelhardt, Professor in the St. Petersburgh Agricultural Institute, was sent by the Ministry of State Domains to investigate the beds of phosphate rock occuring in Central Russia. He was the first to indicate the method for working them and their application. He was accompanied in this expedition by Mr. Yermolov. In the year 1867, the latter went to France and made himself acquainted with the treatment of phosphorites and their application in the Ardennes. Our phosphate rocks very closely resemble in character those of that region, and therefore the results of these investigations proved extremely useful.

In 1868, a mill was built near Kursk by Messrs. Khitrovo, Suslov and Antropov for the

preparation of phosphorites for fertilising purposes, but three years after it failed and was obliged to change its name At the same time a mill for the treatment of phosphorites was established in Riga by Mr. Schmidt, which met with a fair success. In 1872, another was built in the village of Ukolov for the purpose of carrying out the following operations: 1) the grinding of the phosphorite into powder, 2) the increase of the proportion of phosphoric acid, 3) the production of the finest phosphorite powder, 4) the production of superphosphates, 5) the production of perfect and imperfect fertilisers by Will's system. But this mill was also stopped for lack of buyers.

Phosphorite mills and mills for the treatment of bones were at first principally concentrated in the Baltic provinces, where exists the most intensive cultivation occurring anywhere in the whole country. Many farmers making experiments with phosphorites began grinding them in their flour-mills. At the present time there are eight phosphorite mills which are best known. First comes that of Messrs. Koolomzin on the Kornilov farm. Here phosphorites are worked from the Kineshemsk and Makariev districts of the government of Kostroma lying in two continuous deposits in the Jurassic and cretaceous systems. Twenty-six

per cent. of phosphoric acid is guaranteed. The price of this phosphate powder is 30 kop. a pood, inclusive of sack and forwarding to railway-station. If bought by waggon-loads, there is a reduction of 8 per cent. Second in order is the mill belonging to Mr. Miasoyedov on the Bielsk farm, working phosphorites from the Roslavl district of the government of Smolensk, occurring in greensands of the cretaceous system. They shew 15 to 18 per cent. of phosphoric acid, and up to 1 per cent. of potash. The price of this phosphate powder is 25 kop. a pood. The third place is taken by the Company for the Development of the Phosphate Rocks of Riazan, which are derived from the glanconite sandstone. These contain about 18 per cent. of phosphoric acid and as much as 2 per cent. of potash. Fourthly, there is a second mill in the government of Smolensk belonging to Mikhailov. Next, fifth, comes Count Rebinder's mill in Oriol, and sixth, that of Mrs. Burenin in the Morshansk district. The seventh and eighth places are taken by those of Kalichmann and Sannes in the government of Podolia, which are employed in producing superphosphates.

The treatment of phosphorites on the Kornilow estate is as follows. The mineral is dug out and cleansed. In the latter process only

the black nodules composed of solid phosphorite are selected. These are then calcined in a kiln, when a stream of water is sent into the strongly heated mass. This produces simultaneously a chemical effect by decomposing the carbonates, and a physical effect by rendering the calcined stone more easily crumbled and therefore better adapted for grinding. The calcined stone when cooled down is sorted again, after which it passes into the lower division of the mill called the crusher, which breaks it up into pieces about half an inch in diameter. The lumps thus obtained pass under a mill-stone of a type suggested by experience made of particularly hard granite. The ground phosphate so produced is next sifted through a fine meshed sieve, all that which does not pass through being returned to the mill.

A sample is taken from every sack of ground phosphate packed for sale. These samples are then mixed together and sent for analysis to the chemical laboratory. Till 1891, the analyses were carried out by I. A. Grigoriev. After his death, an equally well known chemist, P. D. Nicolaev of the School of Mines, took upon himself this task. The following fluctuations were observed in the composition of the ground phosphate. Analysis among a vast number of cases in the course of six years

shewed only on two occasions 25·4 per cent. of phosphoric acid. Between 26 and 27 per cent. occured, rarely, the almost invariable equivalent being 28, at times 29 or even 29.99. At the Kharkov Agricultural Show for the Whole of Russia in 1887, this article obtained the highest award in the section for ground phosphates, and in 1889 at the Smolensk Agricultural Show it received the large silver medal. It was in 1887 that the Kornilov firm of Messrs. Koolomzin first began to prepare phosphorites. The business was not yet firmly established, and accordingly the information as to its condition in that year is not of a very definite character. From 1888, the firm's accounts become more precise, and shew a clear increase in the number of purchasers of ground phosphate. The total number of persons and institutions applying to the firm either with orders or with enquiries about ground phosphate, for this and the subsequent years are as follows: 1888—223, 1889—183, 1890—248, 1891—398, 1892—707.

The total number of sacks, each containing four poods of ground phosphate, sold on the spot or forwarded by rail, has grown in even greater proportion: in 1888—9030¼, 1889—12831¼, 1891—16226½, 1892—33443½. The table below shews the different classes of buyers:

BUYERS	in 1888	1889	1890	1891	1892
Clergy and Monasteries	37 sacks.	183 sacks.	240 sacks.	446 sacks.	638 3/4 s.
Local Boards (Zemskiya Upravy)	336 »	154 »	401 »	942 1/2 »	1613 »
Peasants	34 »	146 »	306 1/4 »	1088 »	4117 3/4 »
Private Landholders	5628 1/4 »	3380 1/4 »	5241 »	8112 »	10825 »
Agents and Agencies	2995 »	3212 »	6643 »	5438 »	16249 »

These statistics speak for themselves, particularly if it be noticed that the demand for ground phosphate on the part of the peasants increased in five years almost one hundred and twenty times. In many cases the clergy were the first to introduce ground phosphate into a locality, their example being readily followed by the peasantry. An interesting instance of this is that presented by the peasants of the Dorofeev Volost Board of the Makariev district. In 1890 they here bought 50 sacks of ground phosphate, in 1891 the same peasants took 250 sacks, and in 1892 1400 sacks.

With every year the number of customers among the peasants increases in a greater proportion than among the other classes of the population. The explanation of this phenomenon must, it would seem, be sought in the fact that the consciousness of the advantage to be derived from the use of ground phosphate as a fertiliser arose first of all in the class who are nearest to the land, living as they do almost exclusively upon its productions and therefore placing all their hopes in it.

The number of constant customers of the Kornilov firm increases regularly and now reaches *sixty-five*, growing literally every

month *). It is interesting to observe among them the name of A. N. Engelhardt, who has been a purchaser from the very beginning of the working of the Koolomzin phosphorites. Upon the basis of the information for 1892, the number of sacks of ground phosphate bought from the Kornilow firm was distributed according to the place of origin of the orders in the following manner:

I**) 1. Government of Kostroma . . 4332 sacks.
2. » » Tver . . . . 4709 »
3. » » Yaroslav . . 3365 »
4. » » St. Petersburgh: 4311 »
5. » » Moscow . . . 2879 »
6. » » Vladimir . . 2471½ »
7. » » N. Novgorod . 2123 »

Other governments arranged in groups were:

II**) 1. Kaluga, Tula and Smolensk 2051 sacks.
2. Kurland and Livonia . . . . 1849 »
3. Novgorod and Pskov . . . . 1811 »
4. Vilno, Vitebsk, Grodno, Minsk and Mohilov . . . . . 1329 »
5. Yekaterinoslav, Kiev, Tauris . 1079 »

III**) Finally twenty governments: Archangel, Warsaw, Vologda,

*) *Note by the firm.* In January 1893 already many old customers had repeated their orders up to the 25 of January 3675 sacks had been sold and despatched.

**) These three regions I, II, III, are indicated on the map in dark, medium and light red.

Voronezh, Viatka, Kazan, Kursk, Olonets, Oriol, Penza, Perm, Podolia, Riazan, Saratov, Siedlets, Simbirsk, Tambov, Ufa, Kherson, Kharkov and Chernigov, took . . . . . 1134 sacks.

Total . . 33,443½ sacks.

The economical aspect of the business of the working of phosphorites will appear from the following statement.

Account of the cost of production of one pood of ground phosphate:

Digging and carriage of stone . . .	5	kop.
Labour	4·27	»
Repair of mill	1·41	»
Sacks	3·01	»
Rent of land containing deposits . .	1·44	»
Carriage of ground phosphate . . .	2·27	»
Total . .	17·40	kop.

To which must be added taxes, interest on capital (a water and a steam mill), and sinking fund for the same, insurance of building and workmen, laboratory expenses, sieves, management and advertisements. It is hence evident that any considerable fall in the price of a pood of phosphoric powder is not to be

looked for in the present situation of the business.

As was already pointed out above, the merit of shewing the utility of ground phosphate to Russian agriculture belongs in the main to Engelhardt, who was engaged to the last days of his life in carrying out experiments with this fertiliser upon his estate of Batishchevo in the Dorogobuzhsk district of the government of Smolensk, and left behind him a whole series of unfinished experiments. Besides Engelhardt, other farmers, such as Bilderling and Tolstoy, have similarly demonstrated experimentally the undoubted advantages to be derived from the employment of ground phosphate. This has been shewn for several soils, as for example for those which are called «sour» (viz. «podzol», or the soil remaining after burning forest, and marshy soil), and for soils composed entirely or in part of clay or sand, which do not, like the phosphorite soils, contain any large quantity of assimilable phosphoric acid. The experiments in question have been conducted chiefly with crops of rye and other cereals, and upon meadows. The greatest advantages are to be obtained from the employment of phosphate fertilisers in the cultivation of waste lands.

The application of ground phosphate to large farms disposing of only a limited quantity of manure has two advantages. It renders possible the raising of the level of cultivation, so-called more intensive cultivation, upon the nearest lands by carrying all the manure on to them, and at the same time the practice of extensive cultivation upon the distant lands, leaving them from time to time for longer or shorter periods under leguminous crops for the accumulation of nitrogen.

In comparative experiments with superphosphate, it frequently happened that a better crop was obtained from plots dressed with it than from those treated with ground phosphate. This resulted from the chemical state of the powder in the case of superphosphates, in consequence of which the individual particles of phosphate of lime are capable of uniting with the individual particles of the soil, and in this way there is a greater possibility of the roots of plants coming into contact with this nutritious element, than can ever be attained by ground phosphate. On the other hand, the supply of ground phosphate which remains unused goes to the nourishment of subsequent crops, while the supply of superphosphate not assimilated rapidly becomes transformed into a modification which is only

assimilable with difficulty. From an economical point of view the advantage is always on the side of the phosphorites, seeing that a higher interest is obtained upon capital expended. A pood of ground phosphate costs only half as much as a pood of superphosphate, while the proportion of phosphorus contained in it is twice as great.

Experiments with phosphorite as a fertiliser in the Russian chernoziom or blackearth zone, have frequently not given particularly brilliant results, in consequence of the relative richness of these soils in phosphorus, but in comparative experiments with superphosphate, the advantage appeared on the side of phosphorite. This is explained by the high oxydation of superphosphates, which has an injurious effect in the cultivation of plants upon chernoziom. On the whole, phosphorites have the most powerful effect upon our poor northern soils. Of course ground phosphate can be of avail only upon condition of the presence in sufficient quantity of the other nutritious elements, and of the circumstances attending the development of the plant being otherwise favourable. Engelhardt established the fact that to every four hundred square «sazhens» are necessary six poods of phosphoric acid

contained in ground phosphate. Using this proportion, he not unfrequently succeeded in raising the productiveness of his desiatine (2·7 acres) by three, five and even seven extra chetverts (one chetvert = 5·77 bush.) of rye or oats.

As for as concerns the duration of the effect of ground phosphate, cases have been observed of its influence continuing after more than six years had elapsed since dressing; observations over a longer period have not been made in Russia. An extremely interesting experiment upon the different effect of phosphoric acid in dependence upon its condition and proportion in ground phosphate was undertaken by Mr. Dehn upon the Peterhof Experimental Farm The results of this experiment were published in the first numbers of the «Baltische Wochenschrift» (1893). The plant (oat) was grown in vessels filled with quartz sand, to which was added a sufficient quantity of nutritious elements. The selection of the seeds and the general conditions of cultivation were the best possible. The quantity of phosphoric acid taken for each vessel, in each of which one hundred seeds were sown, which some of the results derived from the experiment, are shewn in the following table.

№	Weight of phosphoric acid in lbs.	Name of phosphate fertiliser.	Percentage of phos acid in fertiliser.	Weight of phosphatic manure in lbs	Value of other fertilisers in terms of top crop, taking that of superphosphate as 100.	Crop.			Weight of 1000 grains.
						Grain.	Straw.	Roots.	
I	1/2	Superphosphate	13	3.631	100	33.883	75.75	25.1	27.85
II	1	Phosphorite (Anzimirov's, Riazan)	10	10.000	41.6	11.073	36.2	13.3	17.38
III	1	» » »	23	4.347	49.6	17.875	38.5	14.5	21.49
IV	1	Ground Phosphate (Koolomzin's, Kostroma)	25	4.000	82.9	32.210	61.0	20.9	23.81
V	1	Thomas' slag.	22	4.545	79.1	32.932	57.0	19.7	28.32
VI	2	Ground phosphate (Anzimirov's)	10	20.000	50.4	17.640	39.7	14.5	20.96
VII	2	» » »	23	8.62	72.4	24.830	57.5	20.5	22.49
VIII	2	Ground phosphate (Koolomzin's)	25	8.000	84.4	34.644	66.2	22.0	27.44